MONOENERGETIC EXPERIMENTAL VALIDATION OF A GEANT4 MONTE CARLO CODE FOR BREAST DOSIMETRY APPLICATIONS

Christian Fedon[1], Marco Caballo[1] and Ioannis Sechopoulos[1]

[1] Department of Radiology and Nuclear Medicine, Radboud University Medical Centre, Nijmegen, The Netherlands – christian.fedon@radboudumc.nl; marco.caballo@radboudumc.nl; ioannis.sechopoulos@radboudumc.nl

Introduction: Breast cancer is the second cause of cancer death in women [1]. X-ray digital mammography is the standard screening techinque for millions of women. Notwithstanding this large number, the estimation of the radiation dose suffers of several approximations (e.g. homogenous tissue approximation [2]). Thus, in order to develop a new patient-related method to better estimate the radiation dose, a GEANT4 Monte Carlo (MC) code was developed.
In this work, validation of the code is proposed by comparing the MC output with experimental data for three different dosimeters: radiochromic film (GAF), and thermoluminescence (TLD) and metal oxide semiconductor field effect transistor-based (MOSFET) dosimeters.

Materials and Methods: Monoenergetic, experimental measurements were performed at the ELETTRA synchrotron light source in Trieste (Italy). The beam energy was set to 20 keV. Figure 1 show the 50% glandular, homogeneous semi-cylindrical phantom (CIRS Inc., Norfolk, Virginia, USA) used and the positions of the 30 dosimeters.

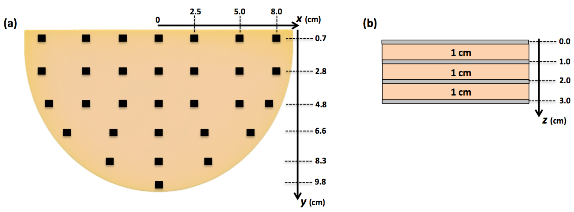

Figure 1. (a) Black squares represent the dosimeters displacement. (b) Sketch of the four investigated depths.

A 2D dose map was obtained using GAF while local dose values were obtained with TLD and MOSFET. All dosimeters are calibrated, in terms of air kerma, against a primary-calibrated ionization chamber for low-energy X-ray.
The experimental setup was reproduced with the MC code. Up to $2x10^9$ photons were emitted by a $12x20cm^2$ planar, rectangular source. The phantom was modeled as a voxellized-homogenous solid. The selected physics lists were the *EMstandard_opt4*. In order to obtain a 2D dose map, a layer of 0.38 mm (i.e. the TLD thickness) was inserted at the depths to be investigated. To reproduce the attenuation of the dosimeters, the material of the layer had the same chemical composition of the TLD. The MC results were then converted from TLD-dose (D_{MC}) to Air-dose (D_{air}) using the ratio of the mass-energy absorption coefficients, as follows:

$$D_{air} = D_{MC} \frac{\left(\frac{\mu}{\rho}\right)_{en}^{air}}{\left(\frac{\mu}{\rho}\right)_{en}^{TLD}}$$

Results: Figure 2 shows the results for 1-cm depth.

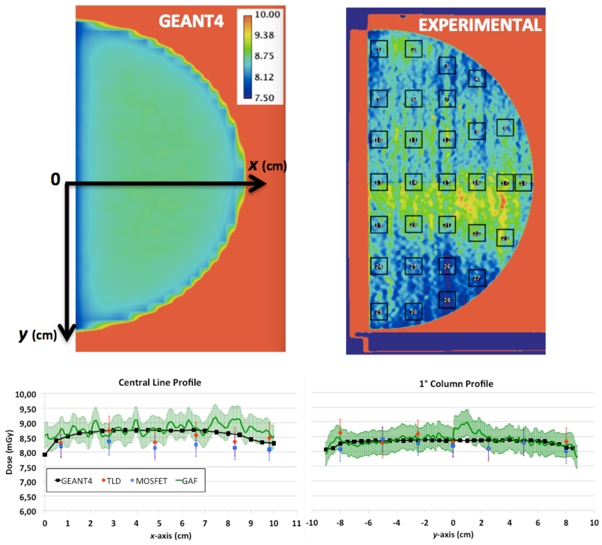

Figure 2. 2D dose map obtained by MC (top left) and GAF (top right), with two profiles shown on the bottom.

The combined standard uncertainty on experimental data is about 6% while the statistical uncertainty for MC is <0.5%. Good agreement is found for all the data within one uncertainty. However, a more homogenous dose distribution is observed for the MC data compared to the experimental ones.
A paired t-test was perfomed for all depths and the results are summarized in Table 1. No difference is found between experimental and MC data.

Depth (cm)	p-value
0	> 0.01
1	> 0.1
2	> 0.1
3	> 0.1

Table 1. Paired t-test results between experimental (i.e. TLD) and MC data.

Conclusions:
A good agreement is found between MC data and experimental measurements (obtained by three different dosimeters). Further work will extend the validation to the polychromatic spectrum (used in clinical practice) and will consider heterogeneous phantom.

References:

1. Cancer Statistic 2016 (R.L. Siegel et al.), *Cancer J Clin.* **66**(1), 7-30 (2016).
2. Characterization of the homogeneous tissue mixture approximation in breast imaging dosimetry (I. Sechopoulos et al.), *Med Phy.* **39**(8), 5050-5059 (2012).